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AN ENGINEERING PROPERTIES OF COMPACTED RED MUD

SATYANARAYANA. P. V. V[1], HANUMANTHA RAO. C. H. V[2] & JAHARA S. K[3]

[1]*Professor, Department of Civil Engineering, A. U. College of Engineering, Andhra University, Vishakapatnam, Andhra Pradesh, India*

[2]*Research Scholar, Department of Civil Engineering, A. U. College of Engineering, Andhra University, Vishakapatnam, Andhra Pradesh, India*

[3]*P.G Student, Department of Civil Engineering, A. U. College of Engineering, Andhra University, Vishakapatnam, Andhra Pradesh, India*

ABSTRACT

Red mud is a solid waste form in the aluminium industry which contributes 150 million tons annually to the solid wastes generated throughout. Huge quantities of Red mud need to be utilized in various Geotechnical applications. Bulk utilization needs an understanding of its behaviour exposed to different energy conditions with respect to structure, compaction and strength behaviour. In the present work Red mud, was studied its engineering properties when it was exposed to different compaction energies and its behaviour is explained with respect to the above characteristics.

KEYWORDS: Red Mud, Grain Size Distribution & Permeability

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Original Article

INTRODUCTION

Red mud is a residue which is obtained during the production of alumina from Bauxite. Huge quantities of Red mud are produced annually (35 million tons from western countries and India) and disposal of this waste is a major problem facing by aluminium industries. Due to its caustic nature, the disposal in the form of Red mud ponds has adverse environmental impacts due to ground water pollution during monsoon. In addition to that disposal/storage requires huge quantities of valuable land (space).

In recent times several attempts have been made to use red mud in various civil engineering applications in the form of bricks, ceramic products, partial replacement to cement, partial substitute for clay. All these utilize small quantities of its production and some of them proven to be economically unsatisfactory.

Researchers have been making efforts to identify Geotechnical characteristics of Red mud. Li L. Y. (1998) identified Red mud as high alkaline, with pH 11-13. Vogt. M. F (1974) observed that it has high frictional angle varying form 38-42^{O}. Somogyi and Grey (1977) and Newson (2002) identified that Red mud has compression index (C_c) in the range of 0.27-0.39 and coefficient of permeability to 2 to 20x10^{-7} cm/s and coefficient of consolidation (C_v) as 3 to 50x10^{-3} cm^2/sec. Subrat K. Rout (2013) identified that Red mud has a specific gravity of 3.34 and ML nature

MATERIALS USED

Red mud: It is collected from the Red mud ponds of NALCO (National Aluminium Company) which is located at Daman Jodi in Orissa, India. Red mud, was collected in wet state; later on it is dried and used for

research purpose.

EXPERIMENTAL STUDY

Red mud is a solid waste obtained from the Bayer's process during Aluminium production. Red mud used for the research purpose was collected from Red mud ponds of NALCO (National Aluminium Company), Daman Jodi, Orissa. The collected Red mud was dried and tested for various Physical, Engineering properties, etc.

Table 1: Physical Properties of Red Mud

S. No	Property		Value
1	Colour		Dark Red
2	Odour		Pungent
3	Texture		Fine
4	Specific gravity		3.05
5	pH		10.4
6	Grain size distribution	Fines (%)	100
7		Silt (%)	90
8		Clay (%)	10

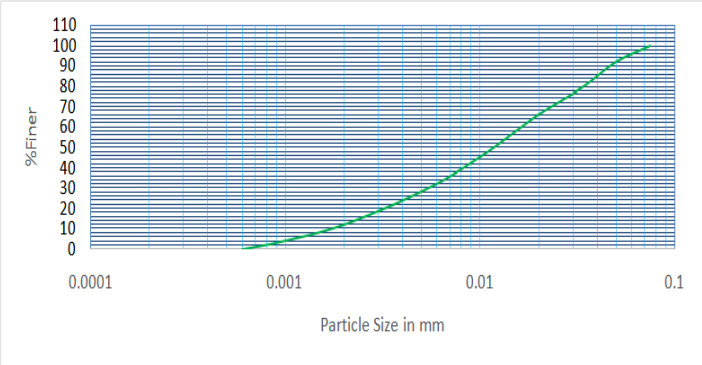

Figure 1: Grain Size Distribution Curve of Red Mud

It's clear from the grain size analysis test data that Red mud contains 100 % fines out of which 92% is Silt size particles (Particle size between $2\mu m\ to\ 75\mu m$) and the remaining 8% is clay size particles($< 2\mu m$)

Consistency Characteristics

Dried Red mud sample was tested for consistency limits such as Liquid limit (W_L), Plastic limit (W_p), Shrinkage limit (W_s) and their allied indices are also determined as per IS 2720, part V & VI and Plasticity chart was developed based on the above values. Red mud was classified "ML" as per IS 1498-1970.

Table 2: Consistency Characteristics of Red Mud

S. No.	Property	Value
1	Liquid Limit (W_L) (%)	32
2	Plastic Limit (W_P) (%)	24
3	Shrinkage Limit (W_S) (%)	20
4	Plasticity index (I_p)	8
5	Shrinkage Index(I_s)	12

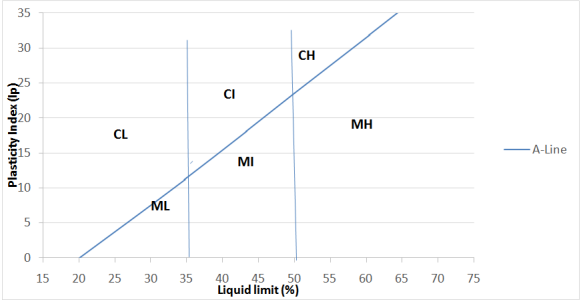

Figure 2: Plasticity Chart of Red Mud

Based on the test data it is clearly known that Red mud is a silt dominating Industrial waste with liquid limit as 32% and Plasticity index as 8. Hence, based on Casagrande's Plasticity chart, it is classified as ML i. e. silt with low compressibility (W_L<35).

Compaction Characteristics

To know the compaction characteristics of Red mud at various compaction energies i. e Standard proctor test as per IS2720-part-7-1983 and Modified Proctor test as per IS2720-part-8-1983 were performed to determine optimum moisture contents (OMC) and Maximum dry densities (MDD)and the test results are shown in table 3 and figure 3 respectively.

Table 3: Compaction Characteristics

Standard Proctor Compaction Test		Modified Proctor Compaction Test	
W %	γ_d	W %	γ_d
10	1.35	9	1.36
12.5	1.40	13	1.46
15	1.46	16.5	1.55
18	1.52	19	1.61
20	1.56	22	1.65
23	1.60	24	1.63
25	1.57	27.5	1.52
28	1.40	30	1.4

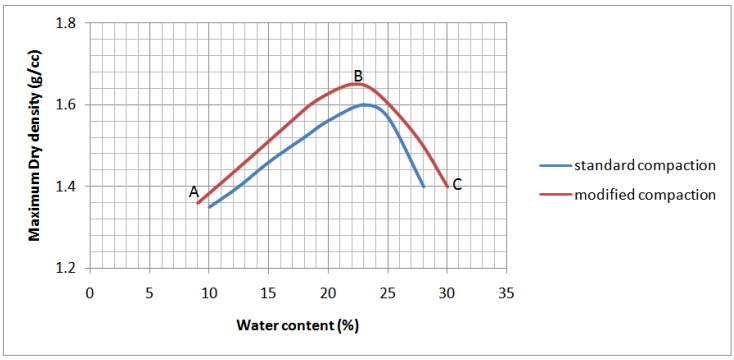

Figure 3: Compaction Curve of Red Mud

From the test results it is identified that increasing compaction energy increases dry densities and decreases water contents. Under modified proctor test Red mud achieved high maximum dry density as 1.65 g/cc and low optimum moisture content as 22% than at standard proctor test i. e. 1.60 g/cc and 23% respectively. Increasing compactive energy helps in filling up of more red mud particles in the formed voids.

At point "A" i. e. at low water contents the Red mud particles are not ready to orient themselves due to capillary forces and at high moisture contents (dry side) red mud particles are ready to achieve an effective orientation and tried to attain flocculated structure while reaching their optimum moisture contents i. e. at point "B". Water contents higher than OMC (wet side) red mud particles lose its flocculated structure (deflocculation) and tries to attain dispersed structure i. e at point "C".

Engineering Properties

To know the engineering properties of Red mud such as coefficient of permeability, unconfined compressive strength, California Bearing Ratio values. Tests as were performed as per IS 2720. The test results are shown in the Table 4.

Table 4: Engineering Properties

S. No	Property	Standard Proctor	Modified Proctor
1	Coefficient of Permeability(cm/s)	8.4×10^{-7}	6.2×10^{-7}
2	Unconfined compressive strength(kPa)	120	140
3	California Bearing Ratio	4	5

From the test results it is identified that increasing the compaction energy increases unconfined compressive strength, CBR values and decreases Coefficient of permeability values. High compaction energy orients the Red mud particles into flocculated structure which helps in increasing shear resistance at particle level in terms of cohesive forces and frictional forces.

Effect of Drainage Conditions on Shear Parameters

To study the shear parameters in total and effective stress conditions by performing various drainage conditions such as unconsolidated undrained, consolidated undrained and consolidated drained tests in the shear box test apparatus at consolidation pressures of 0.5, 1 and 1.5 kg/cm^2 respectively. The test results are shown in the Table 5.

Table 5: Total and Effective Shear Parameters

	Standard Proctor		Modified Proctor	
Test Type	Cohesion (t/m^2)	Ø(deg)	Cohesion (t/m^2)	Ø(deg)
Unconsolidated Undrained	2	30	2.5	32
Consolidated Undrained	0.8	34	1	36
Consolidated Drained	0	36	0	38

From the test results the following observations are made. In unconsolidated undrained test the shear strength is mobilised in terms of both cohesive and frictional forces and it is more pronounced in cohesive forces. During the consolidation process cohesive forces are decreasing and frictional forces are dominating. The shearing resistance of red mud at its drained condition is achieved by frictional forces due to nature of red mud particles in terms of shape and texture. The above phenomena is very effective at high compaction energies. Red mud of excess pore water pressure helps in improving effective stresses, thereby increase in shear resistance values.

Variations of Shear Parameters with Respect to Water Content

Variation of shearing parameters at OMC ± 2 under total stress conditions w. r. t compaction energies.

Table 6: Variation of Shear Parameters with Respect to Water Content

w. c	19		20		21		22		23		24		25	
	S	M	S	M	S	M	S	M	S	M	S	M	S	M
C	2	1	2.1	1.2	2.3	1.5	2.5	1.8	2.3	2	2.1	1.6	2	1.3
ø	30	26	31	27	32	28	32	29	31	30	30	28	28	26

S:Standard Proctor, **M:**Modified Proctor

Modulus of Deformation

Modulus of deformation is also one measure of shearing resistance with respect to load Vs deformation (stiffness). To determine the modulus of deformation (E) unconfined compression strength tests were performed on Red mud samples at their optimum moisture contents with respect to standard and modified proctor conditions as per IS2720-Part 7 &8.

Stress Vs Strain relationships for standard and modified proctor test conditions were generated and modulus of deformation values are computed as the slopes of initial tangents of Stress-Strain curves and the values are shown in table 7 and figure 4.

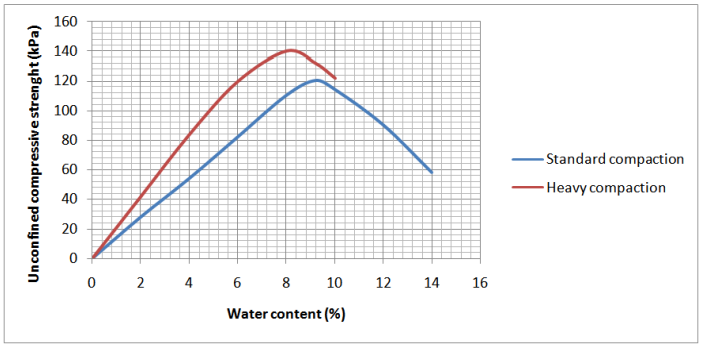

Figure 4: Modulus of Deformation of Red Mud

Table 7: Modulus of Deformation of Soil

Property	Standard Proctor	Modified Proctor
Modulus of deformation: E (kN/m^2)	1.33×10^3	2.2×10^3

From the test results it is observed that Red mud is exhibiting more brittle behaviour at low optimum moisture contents, high, dry densities at high compaction energies than at high optimum moisture contents and low maximum dry densities. It is also observed that high dry densities arrange the particles into flocculent structure which reduces the deformability characteristics.

CONCLUSIONS

- Increase in compaction energy increases maximum dry density values and decreases OMC values.
- High compaction energies orient the red mud particles into flocculent structure.
- Improvement of shear strength, modulus of deformation and decrease of the coefficient of permeability w. r. t increase of compaction energy observed

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